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AN ANNOTATED BIBLIOGRAPHY OF REGULA-
TIONS, STANDARDS AND GUIDES FOR MICRO-
WAVES, ULTRAVIOLET RADIATION AND
RADIATION FROM LASERS AND TELEVISION
RECEIVERS

Lloyd R. Setter, et al

National Center for Radiological Health
Rockville, Maryland

April 1968

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AN ANNOTATED BIBLIOGRAPHY OF REGULATIONS, STANDARDS
AND GUIDES FOR MICROWAVES, ULTRAVIOLET RADIATION AND
RADIATION FROM LASERS AND TELEVISION RECEIVERS

by

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April 1968

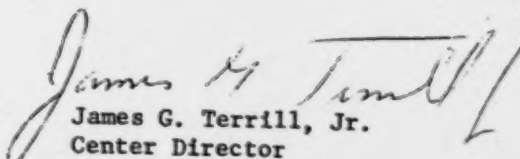
U.S. DEPARTMENT OF HEALTH EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Radiological Health X
Rockville, Maryland 20852

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FOREWORD

The 1967 Congressional Hearings on the control of radiation from electronic products have made clear the need to organize the information on existing regulations, standards and guides developed by Federal, State, and municipal governments, military organizations and nongovernmental organizations. This annotated bibliography was prepared in a form which aids in the comparison of existing or proposed regulations, standards, and guides for further evaluation with respect to adequacy of health protection and control, with consideration given to the economic and technologic factors.

The bibliography was prepared by the Standards and Intelligence Branch in cooperation with the Electronics Products Radiation Laboratory. Copies are available for distribution to organizations and individuals who need the information. The project is a part of the National Center for Radiological Health program of assistance to organizations and individuals who are responsible for protecting the public against the harmful effects of excessive radiation in the portions of the electromagnetic spectrum to which this annotated bibliography relates.


James G. Terrill, Jr.
Center Director

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PREFACE

In preparing this annotated bibliography many individuals were asked to review and comment especially with respect to errors of commission and omission. We wish to thank all those who commented on our bibliography. We especially want to mention the following who made extensive comments and/or suggested documents not in the preliminary draft: Mr. William A. Palmisano, Chief of the Electronics Division, U.S. Army Environmental Hygiene Agency, Edgewood Arsenal; Mr. Louis Costrell, Chief of the Radiation Physics Instrumentation Section, National Bureau of Standards; Dr. Gene P. Grillo, Western Electric; Mr. W. A. McAdams, General Electric Company; Dr. Gordon R. Engebretson, Assistant Director, Department of Environmental Health, American Medical Association; CDR C. F. Tedford, Submarine and Radiation Medicine Division, Department of the Navy; Mr. A. Allan Bates, Chief of the Office of Engineering Standards Liaison and Analysis, National Bureau of Standards; Mr. Andrew D. Hosey, Secretary-Treasurer, American Conference of Governmental Industrial Hygienists; Dr. Bradley, Division of Industrial Hygiene, State of New York; Dr. E. S. Kenney and Mr. Roger Granlund, College of Engineering, Pennsylvania State University; Dr. Martin B. Biles, Director of the Division of Operational Safety, Atomic Energy Commission; Brigadier General Henry C. Dorris, Director of Professional Services, Department of the Air Force; Dr. Leon Goldman, Director of the Laser Laboratory, Children's Hospital, Cincinnati; Dr. Thomas S. Ely, Chairman of the Committee on Radiation Industrial Medical Association, Eastman Kodak Company; Dr. R. Pavenello, Chief of the Environmental Pollution Division,



World Health Organization; Mr. Grant C. Riggle, Biomedical Engineering and Instrumentation Branch, National Institutes of Health; Dr. William T. Ham, Jr., Chairman, Department of Biophysics, Medical College of Virginia; Dr. Wordie H. Parr, Dr. A. S. Brownell, Mr. D. T. Ippolito, Capt. G. R. Peacock, Mr. J. C. Rosenbaum, Sgt. G. C. St. Mary, Dr. E. Spoerl, Headquarters, U. S. Army Medical Research Laboratory; Mr. Herman Garlan, Chief of the Radio Frequency Devices Branch, Federal Communications Commission; Dr. Charles H. Powell, Chief of the Technical Services, Occupation Health Program, National Center for Urban and Industrial Health, Public Health Service; Mr. E. C. Barnes, Director for Radiation Protection, Westinghouse Electric Corporation; Mr. C. Hermas Swope, Research Physicist, American Optical Corporation; and Mr. C. Everett Coon, Staff Engineer, Electronic Industries Association. We are particularly appreciative for Mr. Garlan's permission to reproduce two of the tables by the FCC in the bibliography. Also, we are appreciative to the following National Center for Radiological Health personnel for extensive comments received: Dr. James McTaggart, Dr. Fay M. Hemphill, Dr. Moris L. Shore, and Mr. David H. Flora, Mr. Michael Terpilak and Mr. Richard Peterson. Appreciation is expressed to both the Medical and Occupation Radiation Program and the Technical Services Branch for the use of information in their files.

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13.	Radio-Frequency Radiation Hazard Warning Symbol, 1966, USASI	B	64
14.	Aircraft Fueling and Radar, 1966, USASI	B	65
15.	Field Intensity Measurement Above 300 MHz 1952, IEEE	B	66
16.	Microwave Radiation Hazards, 1967, California	C	67
17.	Safety in Presence of Microwave Generators, 1958, U.S.S.R.	A	70
18.	Radiation Hazards from Electronic Equipment, 1966, Canadian Standards Association	B	71
19.	Safety Precautions Relating to Intense Radio-Frequency Radiation, 1960 British Post Office	C	73

ABSTRACT

✓
This report is an annotated bibliography of guidelines, standards and regulations pertaining to public health protection against selected electromagnetic radiations. The selected portions of the electromagnetic spectrum include microwaves, ultraviolet radiation and radiation from lasers and television receivers. Each category of radiation is treated in a separate section.

Since the terminology for regulations, standards and guides is not uniform among Federal, State, and municipal governments, military organizations and nongovernmental organizations, the annotated documents are classified as Class A, B or C.

→ The annotations include identification of the document, type of standard, intended complier, intended benefitter, limits, specifications and general guidance.

THE AUTHORS

Dr. Setter, Messrs. Snively and Van Wye are staff members of the Radiological Health Standards Section, Standards and Intelligence Branch, and Mr. Solem is a staff member of the Electronics Products Radiation Laboratory, National Center for Radiological Health, Rockville, Maryland 20852.

INTRODUCTION

The purpose of this annotated bibliography is to summarize the information contained in regulations, standards and guides in the United States pertaining to x rays from television receivers, laser beams, ultraviolet radiation and microwaves. Certain documents published in foreign countries and by international organizations were also abstracted. Since standards for protection against ultraviolet radiation are small in number, several excellent references on basic information are given in Section I which contains a summary of radiations in the electromagnetic spectrum. Some guides annotated in the laser section are authored by one or two individuals. These were selected, amongst many available, to represent the current trends providing guidance on laser safety. In this bibliography the information on biological effects has been restricted to that given in the standards documents and the background information in Section I.

The general format for annotation is:

- Subject of document or annotated part of document
- Originating organization or individuals
- Publication identification
- Type of "standard"
- Intended Compliers
- Intended Benefitters
- Limits and Specifications
- General Guidance

The type of standard is classified as either Class A, Class B or Class C.

Class A - A standard, code, criterion, specification, rule, performance requirement, procedure or method which is established or adopted by a governmental body acting under the authority of an act, law or statute.

Class B - A standard, code, criterion, specification, rule, performance requirement, procedure or method that has been prepared and/or adopted by consensus of a committee(s) or commission(s) of technical competence in standards-setting organizations. The standard may be incorporated in whole or in part into a regulation. The standard may have restricted acceptability depending upon the choice or obligation of individuals or users of the standard.

Class C - A guide, standard, code, criterion, specification, rule, performance requirement, procedure or method which has not yet been adopted by a standards-setting organization but which contains information pertinent to the preparation of suitable standards or regulations.

Under TYPE in the annotation are entered the class, the name of the originator and a subclass such as regulation, standard, code and specification as defined by the originator.

The INTENDED COMPLIERS are the individuals or organizations for whom the standard was prepared as stated directly or implied in the document. The INTENDED BENEFITERS are the individuals who are supposed to receive protection.

LIMITS OR SPECIFICATIONS include exposure limits, technical specifications, operating specifications and other information, usually expressed quantitatively. Not all documents include all of these sub-categories of limits and specifications. Quantities specified as exposure limits in the annotations clearly have biological significance. In other cases, the kinds and quantities of radiation that may exist in controlled environments are given. A large number of the regulations of the Federal Communications Commission (FCC) are in this category. These regulations were written as standards for maintaining non-interfering power levels of radio transmitters. The FCC regulations do not necessarily specify safe levels of radiations.

GENERAL GUIDANCE includes a variety of information that is important for health protection. The particular kind varies with the subject of the document.

SYMBOLS

AM	Amplitude modulation
Å	Ångstrom ($1 \text{ Å} = 0.1 \text{ nm} = 10^{-10} \text{ m} = 0.1 \text{ nm}$)
g cal	Gram calorie
eV	Electron volt
dB	Decibel
FM	Frequency modulation
F	Frequency
Hz	Cycles per second
J	Joule
m	Meter
mR	Milliroentgen
RF	Radio Frequency
s	Second
V	Volt
W	Watt

PREFIXES

k	Kilo - 10^3
M	Mega - 10^6
G	Giga - 10^9
m	Milli - 10^{-3}
μ	Micro - 10^{-6}
n	Nano - 10^{-9}
p	Pico - 10^{-12}

DEFINITIONS AND EQUIVALENTS - Continued

EQUIVALENTS

<u>Unit</u>	<u>Equivalent</u>
Electron Volt	1.6×10^{-12} erg
Joule	10^7 erg
Watt	1 joule/sec

SECTION I: THE ELECTROMAGNETIC SPECTRUM

The large majority of regulations, standards and guides pertain to protection against radiations in specific ranges in the electromagnetic spectrum such as gamma, x, ultraviolet, visible, infrared, and microwave radiations. But some guides and excellent background material pertain to several portions of the spectrum. A list of reference books and documents for orientation of the various kinds of radiations in the whole electromagnetic spectrum follows Figure 1.

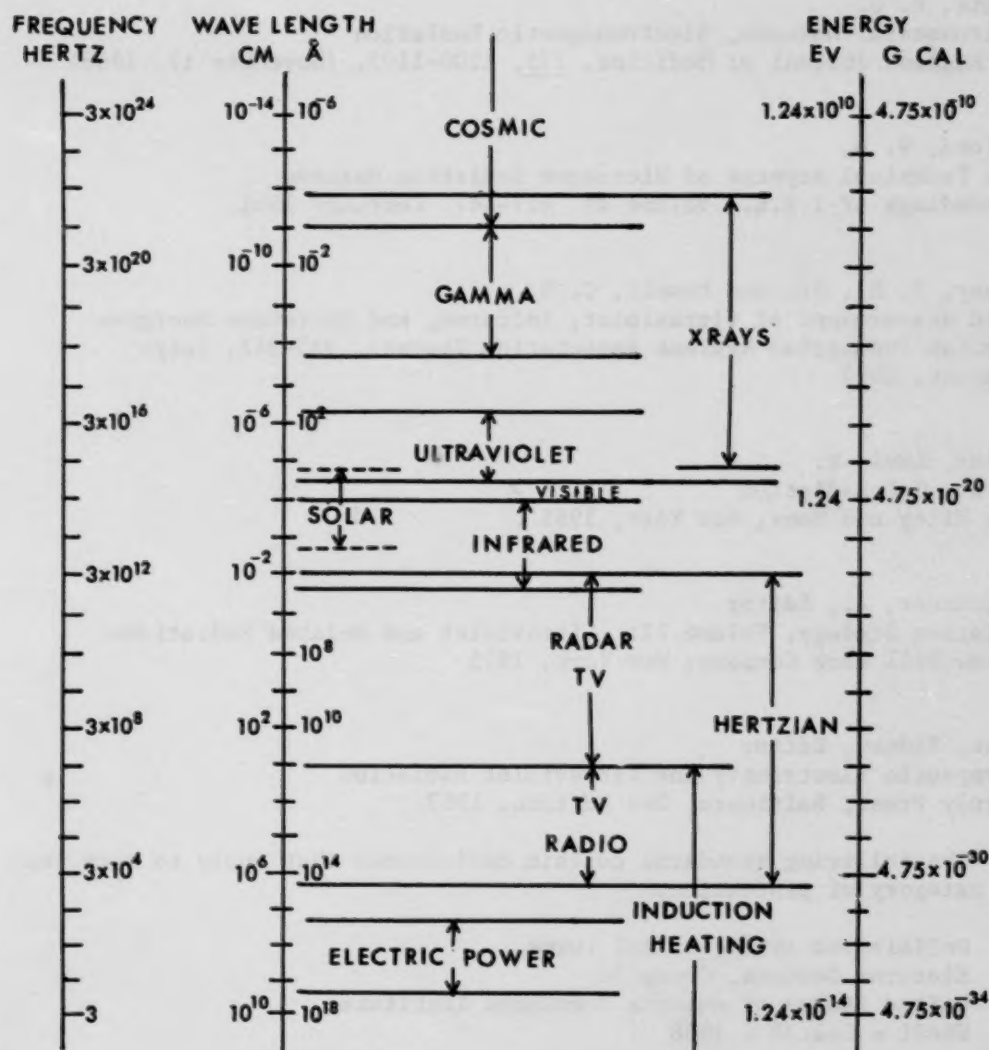


FIGURE 1. THE ELECTROMAGNETIC SPECTRUM

Adapted from article by B. G. Ferris with permission of author and publisher of The New England Journal of Medicine.

By recommending the following references, we do not imply that other references are not also excellent.

- Baetjer, A. M.
Preventive Medicine and Public Health, Edited by P. E. Sartwell,
Chapter 25 on Radiation, 733-757
Appleton-Century-Crofts, New York, 9th Edition, 1965
- Ferris, B. G.
Environmental Hazards, Electromagnetic Radiation
New England Journal of Medicine, 275, 1100-1105, (November 17, 1966)
- Mumford, W. W.
Some Technical Aspects of Microwave Radiation Hazards
Proceedings of I.R.E., Volume 49, 427-447, February 1961
- Fanney, J. H., Jr. and Powell, C. H.
Field Measurement of Ultraviolet, Infrared, and Microwave Energies
American Industrial Hygiene Association Journal, 335-342, July-August, 1967
- Koller, Lewis R.
Ultraviolet Radiation
John Wiley and Sons, New York, 1965
- Hollaender, A., Editor
Radiation Biology, Volume II: Ultraviolet and Related Radiations
McGraw-Hill Book Company, New York, 1955
- Licht, Sidney, Editor
Therapeutic Electricity and Ultraviolet Radiation
Waverly Press, Baltimore, 2nd Edition, 1967
- The following standards contain definitions that apply to more than one category of protection.
- Definitions of Electrical Terms
Electron Devices, Group 70
United States of America Standards Institute
USASI - C42.70 - 1956

Definitions of Electrical Terms
Electrobiology Including Electro Therapeutics, Group 80
United States of America Standards Institute
USASI C42.80 - 1957 -- IEC 50(70)

Although this bibliography is not intended to include an extensive list of publications dealing with basic research on biological effects of laser beams, the following references to work by investigators of laser eye damage are included for background purposes:

Zweng, H. C., Et. al., Experimental Q-switched Ruby Retinal Damage, Archives of Ophthalmology, Volume 78, November 1967.

Ham, William T., Jr., et. al., Effects of Laser Radiation on the Mammalian Eye, Transactions of the New York Academy of Sciences, pages 517-526, February 1966.

SECTION II

X RAYS FROM TELEVISION RECEIVERS

Domestic Television Receivers
Council of State Governments

The Council of State Governments, 1313 East Sixtieth Street, Chicago,
Illinois, 60637, Page 7, Section B.6, October 1964.

Type:

Class B. Suggested State regulations

Intended Compliers:

Domestic television receiver manufacturers.

Intended Benefitters:

General public.

Limits or Specifications:

Domestic television receivers are exempt from licensing and registration providing the dose rate at 5 cm from any outer surface is less than 0.5 mrem/hour.

General Guidance:

None.

X-Ray Protection Standards for Home Television Receivers
National Council on Radiation Protection and Measurements (NCRP)
Interim Statement of the NCRP, 4201 Connecticut Avenue, N.W., Suite 402,
Washington, D.C. 20008, Approved February 23, 1968

Type:

Class B. Recommendation of the NCRP

Intended Compliers:

Manufacturers of home television receivers

Intended Benefitters:

General public

Limits or Specifications:

The NCRP 1959 recommendation "that the exposure dose rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR/hr under normal operating conditions" is reaffirmed. It is stated that the basic intent of the NCRP recommendation will be met if the exposure rate, averaged over an area of 10 cm², does not exceed the stated 0.5 mR in an hour at any external location 5 cm from the surface of the television receiver cabinet.

General Guidance:

The NCRP intends to give further study to the broad problems resulting from the use of radiation-emitting devices by the general public through its recently established Scientific Committee on Radiation Exposure from Consumer Products. This committee will consider in detail the problem of home and other television receivers. It is the judgment of the NCRP that the use of television receivers in the home should not contribute to the annual genetically significant dose of the population in excess of about 5% of the average dose from natural background radiation. The phrase "under normal operating conditions", as used in the 1959 statement, means that the potentially radioactive components, and the set, shall operate within the specifications defined in accordance with accepted industry practices.

X-Radiation Test

Underwriters' Laboratories, Inc. (UL)
Standards for Safety, Radio and Television Receiving Appliances,
UL492, Eleventh Edition, Paragraphs 301 and 302, November 1964
(Paragraphs 301 and 302 revised April 1968)

Type:

Class B. Standard of the Underwriters' Laboratories

Intended Compliers:

Manufacturers whose products bear the UL seal of approval

Intended Benefitters:

General public

Limits or Specifications:

X-radiation test - The X-radiation of a television receiving appliance shall not exceed 0.5 milliroentgens per hour at any point located 5 centimeters from the outer surface of the overall enclosure of the appliances.

The appliance is to be complete, except mechanical parts subject to removal during user servicing may be omitted if they are (1) not necessary for the functioning of the appliance, (2) not exposed to view during normal operation, and (3) not captivated. Adjustable controls are to be adjusted within the range of normal operation of the appliance so as to produce the maximum X-radiation.

General Guidance:

None

Recommended Practice for Measurement of X-radiation from
Display Cathode-Ray Tubes
Joint Electronic Device Engineering Council (JEDEC) Electron Tube Council
JEDEC Publication No. 64, Electronic Industries Association, September 1967

Type:

Class B. Recommended practices for measurement

Intended Compliers:

Manufacturers of cathode-ray tubes

Intended Benefitters:

Manufacturers of cathode-ray tubes and the groups
responsible for compliance

Limits or Specifications:

Recommendations made include the use of an ionization chamber (15 cm in diameter by 10 cm in length) and electrometer combination which shall be calibrated by exposure to a known filtered x-ray field generated at 25 to 35 kV, a stop-watch for measuring exposure time with an accuracy of at least $\pm 1.0\%$, a meter for measurement of the anode (cathode-ray tube) voltage during test with an accuracy of at least $\pm 0.5\%$, and a meter for measurement of the anode current during test with an accuracy of at least $\pm 2.0\%$. The tube under test shall be operated at the required anode voltage and current which shall not vary or drift more than $\pm 0.5\%$ during the entire test period, and radiation measurements should be made at the center of the tube face with 2.5 cm between the tube face and the circular face of the ion chamber and at other positions described in the document.

General Guidance:

The equipment to use in making the measurement, method of calibration, test conditions and the procedure to use are described.

Recommended Practice for Measurement of X-Radiation from Receiving Tubes
Joint Electronic Device Engineering Councils (JEDEC), Electron Tube
Council, JEDEC Publication No. 67, Electronic Industries Association,
February 1968

Type:

Class B. Recommended practices for measurement

Intended Compliers:

Manufacturers of high voltage receiving tubes (rectifiers and
regulators)

Intended Benefitters:

Manufacturers of high voltage receiving tubes and agencies
checking compliance

Limits or Specifications:

1. Survey meter - Victoreen Model 440 RF or equivalent.
Geiger-Mueller counters, proportional counters, scintillation
counters, or solid-state counters may be used provided the
calibration is known over the energy ranges being
measured. Intended as the principal measuring instrument.
2. Ionization chamber - 4.5 inch (11.43 cm) diameter and 4 inch
(10.16 cm) length cylinder ionization chamber (Victoreen
208A or equivalent), used in combination with a minometer.
Used as a secondary measuring instrument or reference
standard.
3. Minometer - Victoreen II Model 687C or equivalent.
4. Timer - A stop-watch or equivalent device with an accuracy of
at least $\pm 1.0\%$.
5. High voltage meter - accuracy of at least $\pm 0.5\%$.
6. Current meter - accuracy of at least $\pm 2.0\%$.
7. Ionization chamber support - constructed of wood or
plastic.

8. Calibration of survey meter and/or ionization chamber and minometer combination - exposure to an x-ray field of such an energy that the half-value layer of aluminum is 0.9 mm (effective energy of 21 keV).
9. Test conditions - regular tube under test shall be operated at the maximum rated high d.c. plate voltage and current which shall not vary more than $\pm 0.5\%$ during the entire test period; rectifier tube shall be tested under d.c. conditions with the d.c. potential, corresponding to the maximum rated peak inverse voltage (total d.c. and Peak), applied to the cathode or filament. Voltage shall not vary more than 0.5% during the entire test period.
10. Procedures - The distance from the surface of the tube under test to the center of the chamber (ionization) shall be 6 inches. Survey meter - radiation measurements shall be made and recorded at the location of maximum stable intensity; ionization chamber - three radiation measurements shall be made at the location of maximum intensity and the average reading recorded (no individual readings shall differ from the average by more than 10%) for regulator tubes and the highest reading for rectifier tubes.

General Guidance:

Recommended are specifications and general guidance on the equipment needed to make the measurements, method of calibration, test conditions, procedures in making the measurements and the information which should be recorded.

Normal Operating Conditions and Ionizing Radiation
(Those pertaining to television sets)

International Electrotechnical Commission (IEC) and International Commission on Rules for the Approval of Electrical Equipment (CEE)

Safety Requirements for Mains Operated Electronic and Related Equipment for Domestic and Similar General Use, IEC Publication 65, Second Edition and CEE Specifications, Publication 1, Third Edition, Section 4.2 and 6, pages 17 and 27, 1965.

Type:

Class B. International safety requirement recommendations.

Intended Compliers:

Manufacturers of apparatus connected to the mains (electric circuit) and intended for domestic and similar general indoor use.

Intended Benefitters:

General public

Limits or Specifications:

Normal operating conditions are considered to consist of the most unfavorable combination of the following conditions (only those which would effect the measurement of x-radiation from television sets are given below):

- a. Any position of normal use of the apparatus, normal ventilation not being impeded. This will be obtained by positioning the apparatus on a horizontal support having dimensions not smaller than that of the apparatus base, leaving a free space of not less than 5 cm depth behind the apparatus.
- b. A supply voltage of 0.9 times or 1.1 times any rated supply voltage for which the apparatus is set. Any rated frequency of the supply voltage. For a.c./d.c. apparatus, a.c. or d.c. supply.
- c. Any position of controls which are accessible to the user for adjustment by hand, except voltage adaptors. Any remote control device connected or not.

The apparatus shall be so constructed that personnel protection against ionizing radiation is provided. Compliance is checked by

measuring the amount of radiation. The dose-rate at any readily accessible point 5 cm from the outer surface shall not exceed 0.5 mR/hr under normal operating conditions. The amount of radiation is determined by a monitor of the ionization chamber type with an effective area between 50 and 100 cm² and with an effective volume between 500 and 1000 cm³.*.

General Guidance:

None

*Added in the November 1967 draft revision of section 6 of the International Electrotechnical Commission Publication 65 "Safety Requirements for Mains Operated Electronic and Related Equipment for Domestic and Similar General Use." This will be effective in April 1968.

Television Sets

International Commission on Radiological Protection (ICRP)
Report of Committee III, ICRP on Protection Against X-Rays up to
Energies of 3 MeV and Beta- and Gamma-Rays from Sealed Sources,
ICRP Publication 3, page 14, Pergamon Press, 1960.

Type:

Class B. Recommendations of the ICRP.

Intended Compliers:

Manufacturers of television sets used in the home or public
places and manufacturers and users of television equipment
such as those used for projection purposes or in closed
circuit applications.

Intended Benefitters:

General public and persons using television set or projection
equipment in their work.

Limits or Specifications:

"The dose-rate at any readily accessible point 5 cm from the sur-
face of any set used in the home or place where the public is
likely to be in close proximity shall not exceed 0.5 mR/hr
under normal operating conditions".

General Guidance:

Television equipment such as those used for projection purposes
or in close-circuit applications shall be so constructed
installed and operated, as to provide adequate protection and
whenever practicable shall be shielded and provided with
interlocks so as to ensure that places where they are used
can be regarded as being outside "controlled areas" thus
avoiding the need for monitoring procedures and special
medical examinations.

Skin, Paragraph 28 under Critical Organs and Tissues
International Commission on Radiological Protection (ICRP)
Recommendations of the ICRP, ICRP Publication 9, page 6,
Pergamon Press, 1966

Type:

Class B. ICRP recommended radiation protection guides

Intended Compliers:

Member countries

Intended Benefitters:

All individuals and populations

Limits or Specifications:

For external exposure of the skin it is recommended that the dose be averaged over an area of 1 cm^2 in the region receiving the highest dose. However, with very narrow beams of extremely high intensity, such as those used for x-ray analysis, the value of such an average dose may be misleading and protective measures have to be based on qualitative considerations.

General Guidance:

None

Domestic Television Receivers
National Committee on Radiation Protection and Measurements
Suggested Radiation Protection Regulations, Draft of Revision to
Appendix B, National Bureau of Standards Handbook 61, Health
Physics Journal, Vol. 5, page 3, April 1961.

Type:

Class C. Draft of a Model Regulatory Code.

Intended Compliers:

Domestic television receiver manufacturers.

Intended Benefitters:

General public

Limits or Specifications:

Domestic television receivers are exempt from registration and the requirements of the proposed regulations providing the dose rate at 5 cm from any outer surface is less than 0.5 mrem/hr.

General Guidance:

None

SECTION III**LASERS**

Laser/Maser Hazards

Department of the Air Force

Air Force Regulation No. 161-24 and memo from Colonel Henry C. Dorris clarifying the regulation, January 12, 1967 and memo March 20, 1967

Type:

Class A. Regulation of the Air Force

Intended Compliers:

Air Force Systems Command (AFSC), Air Force Logistics Command (AFLC) and the Air Force Using Command

Intended Benefitters:

Military and civilian personnel

Limits and Specifications:

The "retinal hazard exposure level" for a ruby laser Q-switched with a pulse duration of 10 to 100 ns is given as an energy density of 0.125 J/cm^2 incident on the retina. In calculating the exposure to the retina, an iris diameter of 7 mm under night conditions and 3 mm for daylight conditions is to be used. In situations where beam enhancement may occur, the calculations should assume the possibility that the energy to the retina may be 100 times greater than would be otherwise expected.

General Guidance:

This regulation gives minimum requirements for medical surveillance in connection with lasers, gives guidance on hazard assessment and assigns responsibilities for evaluating and controlling laser/maser hazards as they apply to AFSC, AFLC and the Using Command. The AF Surgeon General is directed to establish safe laser radiation exposure levels, standardize protective devices, and cooperate with other government agencies to evaluate laser hazards. Other Air Force organizations will provide safety rules and procedures.

Laser System Registration Law
State of Illinois

Laser System Registration Law available from Division of
Sanitary Engineering, Department of Public Health, State of
Illinois. Approved August 11, 1967

Type:

Class A. Illinois statutory law

Intended Compliers:

All operators of laser systems. "Operator" is an individual
group of individuals, partnership, firm, corporation or
association operating or supervising the operation of a laser
system.

Intended Benefitters:

Personnel working with or in the general vicinity of lasers
and the general public.

Limits and Specifications:

No numerical values given. Act enables the Director of the
Public Health to exclude registration of those lasers "where
there is low level energy output. . . .or where . . . the
public health hazard of the laser system is absent or negligible."

General Guidance:

An act to require registration of laser systems, to authorize
the Department of Public Health to investigate and inspect
all laser systems in the State; to require reporting of any
accidental injuries sustained by such laser systems and to
provide injunctive relief and penalties for violations of this
act.

Laser Systems - Code of Practice
 Chief, Safety Officer, Ministry of Aviation, London, England
 British Ministry of Aviation Laser Systems - Code of Practice,
 1965 Edition, Shell Mex. House, London, W.C. 2

Type:

Class A. Code of Practice of the British Ministry of Aviation

Intended Compliers:

Department of the Ministry of Aviation, England

Intended Benefitters:

Personnel who come in contact with lasers during their work and the general public

Limits and Specifications:

Maximum permitted exposure of personnel to laser energy:

Condition	Type of Pulse	Time or Pulse Duration	Permitted Energy Density Falling on Retina
1.	Single pulse	0.001 to 1 μ s	0.001 J/cm ²
2.	Single or train of pulses	1 to 1,000 μ s	0.01 J/cm ²
3.	Pulses or trains of pulses	0.1 s	0.1 J/cm ²
4.	Continuous wave laser power incident upon the retina shall not exceed that value which makes $ab=1.0$, where a =power at the retina (W/cm ²) and b =greatest dimension of the image on the retina (mm).		
5.	Any part of body except eye - total incident laser energy during any one second period shall not exceed 0.1 J/cm ² .		

Acceptable alternatives to the above conditions:

Condition 1 - where the eye cannot resolve the image, the energy density at the pupil of the eye must not exceed 0.02 ergs/cm² indoors or 0.2 ergs/cm² in bright sunlight out-of-doors. Where the eye can resolve the image from a diffuse reflector, viewing is permissible if the energy density at the diffuse reflector does not exceed 0.03 J/cm² indoors or 0.3 J/cm² in bright sunlight out-of-doors. These levels must be reduced three-fold if optical glint occurs.

Condition 2 - Same as alternatives to Condition 1, except permissible energy density is increased by a factor of 10.

Condition 4 - A continuous wave laser of power output less than 50 μ W may be viewed under any conditions.

General Guidance:

The code requires the establishment of "laser - restricted area" around each laser installation unless it can be shown that under conditions likely to prevail no person can receive from the laser installation, radiation exceeding those specified in the code. Specific protection programs are given for the general public with respect to long range (outdoor) laser setups and for laboratory laser systems.

Code of Practice for Research Lasers
Department of Supply Defence Standards Laboratories, Commonwealth
of Australia
Defence Standards Laboratories, Department of Supply, Commonwealth
of Australia, Administrative Memorandum No. 29 of 1966

Type:

Class A. Code of practice for Australian Defence Standards Lab.

Intended Compliers:

All users of research lasers in the Defence Standards
Laboratories, Australia

Intended Benefitters:

All personnel who use or work in the vicinity of lasers in
the Defence Standards Laboratories, Australia

Limits and Specifications:

Energy flux density at the pupil of the eye is required to be
less than:

2 ergs/cm² for pulsed lasers
1 μ W for continuous lasers

General Guidance:

The code specifies that only an operator may view a laser
beam with or without attenuation and then only after two
appropriate professional officers have ascertained by
calculation that there is no risk of damage to the eye
(that the exposure limits are met). Requirements for eye
examinations, reporting of incidents, electrical hazards,
enclosures, and operating instructions are also given.

A Guide for Uniform Industrial Hygiene Codes or Regulations for
Laser Installations
American Conference of Governmental Industrial Hygienists (ACGIH)
Supplement Number 7 to "A Guide for Uniform Industrial Hygiene Codes
or Regulations," Issued by ACGIH April 1949 and Revised May 1965,
1968

Type:

Class B. Recommendations of the ACGIH

Intended Compliers:

Lasers users

Intended Benefitters:

Personnel in the laser control area and other persons likely
to be exposed to their radiations and associated hazards

Limits or Specifications:

Maximum Permissible Exposure Levels for Laser Radiation at the
Cornea for Direct Illumination or Specular Reflection at Wave-
length = 6943 Å.

	Q-Switched 1 ns-1 μ s Pulse P.R.F.* ≤ 10 (ergs/cm ²)	Non-Q-Switched 1 μ s-0.1 s Pulse P.R.F.* ≤ 10 (ergs/cm ²)	Continuous Wave Exposures >0.1 s (μ W/cm ²)
Daylight 3mm pupil	0.5	5.0	50
Laboratory 5mm pupil	0.2	2.0	20
Night 7mm pupil	0.1	1.0	10

*PRF pulsed reoccurrence frequency

These levels can be adjusted for other wavelengths by using a
graph given in the document of energy transmitted to an absorbed
by the retina. A table is given which lists the maximum power
or energy density for which adequate protection is afforded by
glasses of optical density one through 9.

**Maximum Illuminance Permitted for Direct Viewing from A
Diffuse Surface Reflection as Measured at the Reflecting
Surface**

	<u>Q-Switched Pulse J/cm²</u>	<u>Non-Q-Switched Pulse J/cm²</u>	<u>Continuous Wave Laser W/cm²</u>
Daylight 3mm pupil	0.45	5.5	13.5
Laboratory 5mm pupil	0.15	2.0	6.0
Night 7.5mm pupil	0.070	0.9	2.5

General Guidance:

Recommendations are made on exposure criteria, associated hazards involved in laser operations, hazards controls, personal protection, ventilation, electrical hazards, medical surveillance and hazards evaluation.

Laser/Maser Hazards

Ground Electronics Engineering - Installation Agency Standard, U.S. Air Force

T.O. 31Z-10-4, Technical Manual, Electromagnetic Radiation Hazards, Change 1 Notice, Chapter 3, Section VII, Paragraphs 3-254 to 3-262, August 1, 1966

Type:

Class C. General guide on laser hazards

Intended Compliers:

Air Force personnel using or working near lasers

Intended Benefitters:

Air Force Personnel

Limits or Specifications:

None

General Guidance:

Discusses general safety precautions in the use of lasers and where to seek guidance on the subject.

Laser Safety

U.S. Atomic Energy Commission (AEC)

Draft of an addition to the AEC Standard Operating Procedure at the Nevada Test Site (NTS), NTSO-05X1, February 8, 1968

Type:

Class C. Draft of an addition to the AEC Standard Operating Procedure, Nevada Test Site Organization, based on the recommendations made by the Laser Safety Conference held on October 19-20, 1967 at Las Vegas, Nevada

Intended Compliers:

Users of lasers on the Nevada Test Site

Intended Benefitters:

Personnel working on the test site and the off-site population

Limits or Specifications:

<u>Type of Laser</u>	<u>Type of Pulse</u>	<u>Duration of Single Pulse</u>	<u>Permitted Energy or Power Density Directly Falling on Cornea</u>
1. Infra-red ($>14,000 \text{ \AA}$)	Single Continuous	Not specified -----	$0.1 \text{ J/cm}^2/\text{pulse}$ 1.0 W/cm^2
2. Visible and near infra-red ($4000 \text{ \AA}$ to $14,000 \text{ \AA}$)	Pulses with an off time between pulses of $\geq 100 \text{ ms}$ Continuous	$<100 \text{ ns}$ $\geq 100 \text{ ns}$ -----	0.1 W/cm^2 peak power $0.1 \text{ ergs/cm}^2/\text{pulse}$ $3\mu\text{W/cm}^2$
3. Ultraviolet ($<4000 \text{ \AA}$)	Not specified	Not specified	$0.5\mu\text{W/cm}^2$ average power

For lasers operating in the ultra-violet, visible, near infra-red, and infrared portions of the spectrum, the maximum intensity incident on the skin, excluding the eye is $0.1 \text{ J/cm}^2/\text{pulse}$ or 1.0 W/cm^2 for continuous lasers.

General Guidance:

Responsibilities and general procedures for laser safety associated with NTS programs are given. All lasers used at NTS are required to be registered except continuous wave lasers equal to or below 2 mW total beam power.

Eye and Skin Protection, Environmental Exposures, and Electrical Hazards
 Laser Safety Conference, Cincinnati, Ohio, January 29 to 31, 1968
 Recommendations of the Workshops on Eye Protection and Environmental Exposures, Skin Protection and Electrical Hazards held at the Laser Safety Conference, University of Cincinnati, sponsored by the Medical Laser Laboratory of the Children's Hospital of the University of Cincinnati, National Center for Urban and Industrial Health of the U.S. Public Health Service and the Department of Environmental Health of the College of Medicine of the University of Cincinnati.

Type:

Class C. Recommendations made at a Laser Safety Conference

Intended Compliers:

Users of lasers

Intended Benefitters:

Personnel working in installations or areas containing lasers

Limits or Specifications:

Suggested conservative guidelines for permissible irradiation at the cornea for a wavelength of 6943 Å are:

	<u>3mm pupil diameter</u>	<u>7mm pupil diameter</u>
Q-Switched pulsed (ergs/cm ²)	0.5	0.1
Non-Q-Switched pulsed (ergs/cm ²)	5.0	1.0
Continuous wave (μW/cm ²)	5.0	1.0

For all lasers operating in the visible, near infrared and infrared ranges, the maximum intensity incident on the skin, excluding the eye shall be:

0.1 J/cm²/pulse for pulsed lasers, and
 1.0 W/cm² for continuous wave lasers

General Guidance:

Mention was made of the different means of eye protection and the need for proper identification and labelling of laser goggles. For environmental evaluation of by-products produced by laser impacts on various target materials it was recommended that standard industrial hygiene, analytical, toxicological, health physics and microbiological methods be used. Electrical hazards need to be further defined and worked on but the knowledge required to solve such problems is available.

The Evaluation of Laser Hazards

Sloney, David H. and William A. Palmisano

Presented at the American Industrial Hygiene Association Meeting,
Chicago, Illinois, May 14, 1967

Type:

Class C. Guide suggested by author

Intended Compliers:

Laser users

Intended Benefitters:

Personnel using or working near lasers

Limits and Specifications:

Permissible occupational exposure levels for laser radiation
at the cornea for direct illumination or specular reflection
at a wavelength of 6943 Å:

	Daylight <u>3mm pupil</u>	Laboratory <u>5 mm pupil</u>	Night <u>7.5 mm pupil</u>
Q-switched pulse (ergs/cm ²)	0.5	0.2	0.1
Non-Q-switched pulse (ergs/cm ²)	5	2	1
Continuous wave laser (μW/cm ²)	5	2	1

The values are considered to include a safety factor of 10. These levels can be adjusted for other wavelengths by using given graphs of energy transmitted to, and absorbed at, the retina and normalizing the curve at 6943 Å. These adjusted levels should not exceed the above corresponding levels by a factor greater than 10. As a guideline, permissible exposure levels for the skin should not exceed the night time levels for the eye by a factor of more than 10⁵, ultraviolet excepted.

General Guidance:

General environmental and personal protective safeguards are given which apply to many laser situations. Also included are specific precautions to be followed when using high

powered laser, low powered gas and continuous wave semiconductor lasers, CO₂-N₂ lasers, and outdoor laser setups. A method of hazard evaluation for the eye is given along with guidance on exposure control.

What You Should Know About Laser Safety
Martin-Marietta, Orlando Division
OR 6672-9/65, Rev. 11/65, Martin-Marietta, Orlando Division

Type:
Class C. Martin-Marietta Company Guide

Intended Compliers:
Laser users

Intended Benefitters:
Occupational workers and visitors to laboratory

Limits and Specifications:
Eye safety level:

Pulse Duration

30 ns

Continuous wave

Permitted Energy Density
Falling on the Retina

0.01 J/cm²

0.1 J/cm² during any period
of 0.1 s

General Guidance:
Specific eye hazard nomograms to evaluate exposure hazards, general safety rules for pulsed (solid state), gas, and injection lasers, and personnel protective devices are given.

Guidelines for the Safe Use of Lasers

Worden, F.X., W.C. Roberts, M.D., and J.P. Dunn, M.D.

General Medical Director's Organization, Western Electric Company

Type:

Class C. Western Electric Company guide

Intended Compliers:

Western Electric Company employees using or working near lasers

Intended Benefitters:

Western Electric Company employees

Limits or Specifications:

The guideline states that not enough is known about laser eye damage to set definite exposure limits but that some suggested permissible exposure limits may be found in the Martin-Marietta laser safety booklet, the Ministry of Aviation Code of Practice for laser systems, or in an article by Leon Goldman, M.D., called "Personnel Protection from High Energy Lasers" in the American Industrial Hygienist Association Journal of November-December 1965, page 553.

General Guidance:

Responsibilities are assigned to the various organizations within the company to follow appropriate procedures related to lasers. The organizations are Engineering, Medical, Industrial Hygiene, Safety, and Purchasing. Each is designated appropriate tasks related to laser safety so that the company has a unified, comprehensive laser safety program. Instructions for each organization are somewhat general; details are worked out through inter-organization cooperation.

Personnel Protection from High-Energy Lasers
 Goldman, Leon, M.D. and Peter Hornby
 American Industrial Hygiene Association Journal, Vol. 26
 pages 553-557, November-December 1965

Type:

Class C. Guide suggested by author

Intended Compliers:

Laser users

Intended Benefitters:

Personnel using or working near lasers

Limits and Specifications:

This paper gives "safe energy levels" for eye damage which the authors state are presently used. These are:

	<u>Energy Density or Power Density Falling on the Cornea</u>
1. Gas laser (6328 Å)	1 μ W/cm ²
2. Pulsed ruby laser (6943 Å)	1 erg/cm ²
3. Pulsed neodymium laser (10,600 Å)	10 ergs/cm ²
4. Q-switched ruby laser (6943 Å)	0.1 ergs/cm ²

General Guidance:

This paper gives guidance on a laser protection program which centers on personnel control (eye protection, skin protection, protection from air contamination due to the use of lasers), and area control (avoidance of specular reflectance, proper ventilation, avoidance of electrical shock).

Hazards of Laser Radiation: Mechanisms, Control and Management
Litwin, Martin S., M.D., et al.
American Industrial Hygiene Association Journal, Volume 26,
No. 1, pages 68-75, January-February 1967

Type:

Class C. Guide suggested by author.

Intended Compliers:

Laser users

Intended Benefitters:

Personnel using or working near lasers

Limits or Specifications:

Suggested as a useful guideline for protection, as far as short-term effects are concerned, is the minimal threshold dose of radiation required to produce injury. The statement is made that, in general, the retinal damage threshold dose for a 6943 Å non-Q-switched millisecond exposure is within the range of 0.5 to 1 J/cm² calculated to be incident on the retina. Injury threshold at high-peak-power levels using a Q-switched system appears to decrease with decreasing pulse duration. These data used with a safety factor of at least 100, provide guidelines for radiation protection standards at the ruby wavelength.

General Guidance:

This paper gives guidance on the control of laser hazards through general administrative procedures (personnel, medical supervision, records), laboratory design, protection standards and dosimetry.

Safeguarding Lasers
Zaret, Milton, M., M.D.
National Safety News, February 1965

Type:
Class C. Guide suggested by author

Intended Compilers:
Laser users

Intended Benefitters:
Personnel using or working near lasers

Limits and Specifications:
No exposure limits are given

General Guidance:

This article includes a compilation of recommended safe practices for laser users prepared by T.H. McBrien, Safety Supervisor, Aerospace Division of Westinghouse Electric Corporation and member of the Cheasapeake Chapter, A.S.S.E. The compilation includes recommendations from: the Association of Casualty and Surety Companies, Leonard R. Solon, Bell Telephone Laboratories, Dr. Milton Zaret and Michael Sykos.

Laser Safety Considerations

Brown, P., Jr.

RCA Laboratories, Princeton, New Jersey, July 8, 1966

Type:

Class C. Guide suggested by author

Intended Compliers:

Personnel using or working near lasers

Intended Benefitters:

Personnel using or working near lasers

Limits and Specifications:

The report states that there has not been general agreement with respect to safe exposure levels. Some upper levels are suggested, however, for light incident on the cornea:

<u>Pulse Duration</u>	<u>Suggested Upper Limit of Power Density Incident on the Cornea</u>
Milliseconds and shorter	500 $\mu\text{W}/\text{cm}^2$ peak power density
Continuous Wave	500 $\mu\text{W}/\text{cm}^2$

General Guidance:

Eye protection and a hazards control program are the two main subjects of the report. The report lists precautions to be observed when protective goggles are used, and also contains some general guidelines for safety procedures to prevent accidental exposure to laser radiation in the laboratory. No mention is made of a medical program,

SECTION IV

ULTRAVIOLET RADIATION

Head, Eye and Respiratory Protection Safety Code
United States of America Standards Institute
USASI - Z 2.1-1959

Type:

Class B. USASI standard

Intended Compliers:

Persons exposed to ultraviolet, infrared and excessive visible radiation

Intended Benefitters:

Compliers and general public

Limits and Specifications:

Specifications are the same as those in:

Spectral-Transmissive Properties and Use of Eye-Protective Glasses
United States National Bureau of Standards
NBS Circular 471, October 8, 1948

General Guidance:

This standard incorporates specifications established by the National Bureau of Standards. NBS has numbered the various shades of filter lenses which correspond to specific spectral transmittances. Lenses which reduce the intensity of visible radiation should be used only where exposure to excessive sunlight or glare occurs. The use of tinted lenses inside of homes and offices is not recommended since the level of illumination indoors is low. The use of dark glasses at night for reducing the glare from automobile headlights also is considered inadvisable since the visibility of all other objects is reduced. In selecting glasses for industrial exposures, it should be noted that lenses which reduce visible light may not remove either the ultraviolet or infrared radiation produced in the industrial process.

A Standard Source of Ultraviolet Radiation for Calibrating Photoelectric Dosage Intensity Meters

United States National Bureau of Standards (NBS)

Research Paper RP858, Journal of Research of the National Bureau of Standards, Volume 16, pages 83-92, February 1936

Type:

Class B. NBS Standard Source Description

Intended Compilers and Benefitters:

Manufacturers and users of sources of ultraviolet radiation

Limits and Specifications:

The ultraviolet output of the quartz mercury-arc lamp was regulated to 2 or 3 parts in 1500, as measured with a photoelectric ultraviolet meter.

General Guidance:

Abstract:

The advantages and disadvantages of sources emitting either a continuous or a discontinuous spectrum are considered in connection with the use of such lamps as a standard of ultraviolet radiation.

It is shown that because of the high intensity and favorable distribution of the ultraviolet emission lines at 2967 to 3132 Å, the quartz mercury-arc lamp is well adapted for standardizing photoelectric ultraviolet dosage intensity meters in absolute units.

A description is given of the installation of a commercial 110-volt vertical quartz mercury Uviarc lamp, and of methods of calibrating its ultraviolet output in absolute units.

By calibrating photoelectric ultraviolet intensity meters against a laboratory standard, a great reduction is effected in equipment required for field measurements of ultraviolet solar radiation.

Acceptance of Ultraviolet Lamps for Disinfecting Purposes
American Medical Association (AMA)
Report of the Council on Physical Medicine
Journal of the American Medical Association, Volume 137, pages 1600-1603
(August 28, 1948)

This report is an authorized revision of the previous statement, "Acceptance of Ultraviolet Lamps for Disinfecting Purposes", J.A.M.A., 122, 503 (June 1943)

Type:

Class C. AMA Acceptance Requirement

Intended Compliers:

Manufacturers and users of ultraviolet lamps in hospitals nurseries and operating rooms.

Intended Benefitters:

Patients, staff and bystanders in hospitals, nurseries and operating rooms

Limits and Specifications:

The total intensity of the ultraviolet radiation (diffusely reflected from the walls and fixtures and emanating directly from the lamp) incident on the occupant for seven hours or less should not exceed five-tenths microwatt per square centimeter ($0.5 \mu\text{W}/\text{cm}^2$) and for continuous exposure (twenty-four hours a day) should not exceed 0.10 microwatt per square centimeter of wavelength 2,537 Å.

The data governing the Council's Acceptance of Sun Lamps show that exposure to an intensity of 36 microwatts per square centimeter of radiation of wavelength 2,537 Å produces an erythema in about fifteen minutes

General Guidance:

The total amount of direct and scattered ultraviolet radiation incident on the occupants must be kept below the level that will produce conjunctivitis, erythema and any other injurious physiologic effects that may arise from prolonged irradiation. This requirement should be met by a suitable arrangement of the lamp fixtures and light baffles and not by requiring the occupants of hospital wards and nurseries to wear glasses and a special covering of the parts of the body (face, hands) normally uncovered.

General Guidance: (Continued)

Recent developments indicate that reflected ultraviolet intensities in excess of that specified by the Council should be remedied by painting all ordinary and all perforated acoustic ceilings with a standard oil paint or by painting nonperforated acoustic materials with a coat of ordinary glue wall size.

Requirements for Acceptance of Ultraviolet
Lamps for Disinfecting Air

Clinical evidence submitted to the Council shows that under properly controlled conditions killing of air-borne micro-organisms by ultraviolet rays may be used to supplement other methods of disinfecting air for prevention of cross infection and contagious wards in nurseries and hospitals and for reducing and hospitals for reducing air-borne infection of wounds in operating rooms. The deleterious effects of ozone generated by ultraviolet lamps are recognized. The Council therefore requires for acceptability of ultraviolet disinfecting lamps that, under suitable ventilation, in the space near the occupants of the room the concentration of ozone shall not exceed 1 part in 10,000,000. However, in view of the researches by Witheridge and Yaglou showing that a much lower concentration (1 part in 25,000,000) is irritating to the mucous membranes of the upper respiratory tract, this specification of 1 part in 10,000,000 is tentative, awaiting confirmation of the evidence that a lower concentration of ozone is desirable in nurseries and hospital rooms occupied twenty-four hours a day. If the odor of ozone is distinctly perceptible the Council recommends increased ventilation.

Recently manufacturers have determined on the manufacture of two kinds of ultraviolet disinfecting lamps: (1) the type "L" lamp that generates a low amount of ozone and (2) the type "H" lamp that produces a high amount of ozone. The Council accepts only the type "L" lamp, that generates practically no ozone.

In considering ultraviolet generators for disinfecting purposes, the Council makes no distinction between lamps for use in air conditioning ducts and lamps for use in open rooms in which there is only a slow circulation of air. In both cases, a sufficient number of lamps must be provided to insure adequate disinfection of the air as determined by approved culture tests or other accepted procedures. So that an ultraviolet output above the minimum value for adequate disinfection may be maintained, the Council recommends that the ultraviolet intensity of each lamp unit be measured at least once a month. To comply with the Council's requirements the ultraviolet spectral, energy distribution of the disinfecting lamp shall be comparable in lethal effectiveness with the low vapor pressure mercury discharge tube in which the dominant radiation is of wavelength $2,537\text{\AA}$.

General Guidance (continued)

The minimum intensity at right angles to and at a distance of 1 meter from the plane of the lamp tube in its fixture shall not be less than the germicidal equivalent of 20 microwatts per square centimeter of homogeneous radiation of wavelength 2,537 Å. The useful life of the lamp shall not be less than four thousand hours. During this period the ultraviolet output shall not fall below the herein specified minimum intensity. To meet this requirement the lamp may be provided with a voltage regulator to compensate for the decrease in intensity of ultraviolet with usage; or the lamp may emit a sufficient excess of ultraviolet radiation when new, so that the output shall not fall below the specified minimum value ($20 \mu\text{W}/\text{cm}^2$ at 1 meter) in less than four thousand hours' operation. In either case the installation shall be provided with adequate safeguards against overexposure of the occupants of the room to ultraviolet radiation. The burner of the lamp shall be of glass or of suitable filter jacketed quartz, highly transparent to the emission line at 2,537 Å, and opaque to radiation of wavelengths shorter than 2,200 Å, to prevent the generation of an injurious amount of ozone, largely produced by these short wavelengths. To insure compliance with these requirements the lamp may consist of one, two or three tubes, mounted and operated as a unit.

For consideration of acceptance by the Council, the manufacturer shall submit a lamp unit in its fixture, permanently marked as to its useful life, and its radiant flux in microwatts per square centimeter of wavelength 2,537 Å, at 1 meter under the normal power input used to insure a useful life of not less than four thousand hours. In addition the manufacturer shall submit satisfactory clinical evidence, obtained over a period of not less than four winter months, of the effectiveness of an installation of such lamps in maintaining adequately sterilized conditions in the space (hospital, nursery) subjected to radiant disinfection.

**Spectral-Transmissive Properties
and Use of Eye-Protective Glasses**
United States National Bureau of Standards
Circular 471 by Ralph Stair (supersedes Circular C421)
October 8, 1948

Type:

Class C. NBS guide

Intended Compliers:

Manufacturers, users and persons otherwise exposed to
harmful ultraviolet, visible or infrared radiation.

Intended Benefitters:

Users and persons otherwise exposed.

Limits and Specifications:

Tables and graphs from which safe limits can be derived are
given in the document.

General Guidance:

This paper contains spectral-transmissive data on most of the
widely distributed brands and types of glasses employed in
protecting the eyes from harmful ultraviolet, visible, or
infrared radiant energy, which may be encountered in industry,
in driving, or while at home or at play. The standardization
of shade numbers for protective glasses used in industry, glasses
for special welding operations, the use of colored glasses for
night driving, and the elimination of glare in sunlight are
given considerable attention.

SECTION V**MICROWAVES**

Radio Frequency Devices
Federal Communications Commission (FCC)
Code of Federal Regulations, Title 47, Part 15

Type:

Class A. U.S. Government regulation

Intended Compliers:

Radio stations that may interfere with radio communications,
and manufacturers

Intended Benefitters:

Radio stations and general public

Limits and Specifications:

(See next 2 pages)

General Guidance:

Radio frequency devices may be operated without a license provided they meet the limits in Part 15 and provided they do not cause interference to communications of licensed stations. If interference is caused, the RF device becomes subject to the licensing requirements of the Communications Act of 1934.

PART 15 - TECHNICAL SPECIFICATIONS

TYPE OF APPARATUS	FREQUENCY RANGE	FIELD STRENGTH ($\mu\text{V/m}$)
RADIO RECEIVERS (Applies only to receivers that operate between 30-890 MHz)	0.45- 25 MHz 25 - 70 MHz 70 - 130 MHz 130 - 174 MHz 174 - 260 MHz 260 - 470 MHz 470 -1000 MHz	NOTE 1 32 at 100 ft. 50 at 100 ft. 50-150 at 100 ft.* 150 at 100 ft. 150-500 at 100 ft.* 500 at 100 ft. (NOTE 10) *linear interpolation
COMMUNITY ANTENNA TV SYSTEMS	Up to 54 MHz 54 - 132 MHz 132 - 216 MHz Over 216 MHz	15 at 100 ft. 20 at 10 ft. (NOTE 2) 50 at 10 ft. (NOTE 3) 15 at 100 ft.
LOW POWER COMMUNICATION DEVICES (miniature transmitters)	10 - 490 Hz	$\frac{2400}{F_{\text{Hz}}}$ at 1000 ft
	Alternative for 160 - 190 Hz	1 watt input & 50 ft. antenna
	510-1600 Hz	$\frac{24000}{F_{\text{Hz}}}$ at 100 ft. or 100 milliwatts input & 10 ft. antenna
	26.97-27.27 MHz	NOTE 4
	Above 70 MHz	NOTES 5 & 6
RADIO CONTROLS FOR DOOR OPENERS (Garage door controls)	Below 70 MHz	NOTE 7
	Above 70 MHz (NOTE 8)	NOTE 5
WIRELESS MICROPHONES AND TELEMETERING DEVICES	88-108 MHz	NOTE 9
ALL OTHER RESTRICTED RADIATION DEVICES	All frequencies	15 at $\frac{\lambda}{2\pi}$ $\frac{\lambda}{2\pi} = \frac{157,000}{F_{\text{Hz}}} \text{ ft.}$

NOTES

NOTE 1 In lieu of field strength, a maximum power line RF voltage is specified.

For TV receivers at all frequencies: 100 μ V

For all other receivers: 0.45- 9 MHz 100 μ V

9 -10 MHz 100-1000 μ V*

10 -25 MHz 1000 μ V

*linear interpolation

NOTE 2 In a sparsely inhabited area**, this value is increased to 400 μ V/m at 10 ft.

NOTE 3 In a sparsely inhabited area**, this value is increased to 1000 μ V/m at 10 ft.

**A sparsely inhabited area is an area where TV signals are not in fact being received within 1000 ft. of the system.

NOTE 4 The FCC regulations do not specify a field strength. In lieu thereof, operation is limited to a maximum of 100 milliwatts input to the final RF stage with a single element antenna not more than 5 ft. long.

NOTE 5 These devices must meet the field strength limitations prescribed for receivers up to 1000 MHz. Above 1000 MHz the field strength must not exceed 500 μ V/m at 100 ft.

NOTE 6 Radiation must be limited to one second duration followed by at least a 30 second silent period.

NOTE 7 Operation is limited to frequencies and conditions specified for Low Power Communication Devices.

NOTE 8 Radiation is prohibited in the following frequency bands:

MHz	MHz	GHz
73 - 75.4	608-614	10.68-10.70
108 -118	960-1215	15.35-15.4
121.4-121.6	1400-1427	19.3 -19.4
242.8-243.2	1535-1670	31.3 -31.5
265 -285	2690-2700	88 -90
328.6-335.4	4200-4400	
404 -406	4990-5250	

NOTE 9 Radiation within a 200 Hz band centered on the operating frequency must not exceed 50 μ V/m at 50 ft. All other radiation is limited to 40 μ V/m at 10 ft.

NOTE 10 For television receivers the limit 500 μ V/m is temporarily increased to 1,000 μ V/m. All other receivers must comply with the 500 μ V/m limit.

**Industrial, Scientific and Medical Equipment That May
Interfere With Radio Communications**
Federal Communications Commission (FCC)
Code of Federal Regulations, Title 47, Part 18

Type:

Class A. United States Government regulation

Intended Compliers:

Users of industrial, scientific and medical equipment that
may interfere with radio communications

Intended Benefitters:

Users of equipment and public

Limits and Specifications:

(See next page)

General Guidance:

The regulations (1) set forth the conditions under which the operation of equipment is considered not to cause interference and is therefore not required to be licensed, and (2) provide a licensing procedure for ISM equipment whose operation is a source of interference.

For operation without a license, the equipment must operate without causing interference to the communications of any licensed station; unlimited radiation is permitted on the ISM frequencies but radiation must be limited as prescribed on all other frequencies; the equipment must be type approved or certificated; the equipment and the location shall be available for inspection.

The following are designated as the ISM frequencies:

13.56	MHz	± 6.78	kHz	.915	GHz	± 25	MHz
27.12	"	± 160	"	2.45	"	± 50	"
40.68	"	± 20	"	5.8	"	± 75	"
				22.125	"	± 125	"

PART 18 - TECHNICAL SPECIFICATIONS

INDUSTRIAL HEATING EQUIPMENT	NOTES																
10 $\mu\text{V/m}$ at 1 mile	NOTE 1																
MEDICAL DIATHERMY EQUIPMENT (a) Operating on 13.56, 27.12, 40.68 MHz 25 $\mu\text{V/m}$ at 100 ft. (b) Operating on 915; 2,450; 5,800; 22,125 MHz; See NOTE 4. (c) All other equipment: 15 $\mu\text{V/m}$ at 1000 ft.	ISM stands for industrial scientific, and medical equipment and includes devices which use radio for noncommunication purposes. NOTE 2 The following frequencies are allocated for use by ISM equipment with the tolerance limits specified:																
ULTRASONIC EQUIPMENT (a) Radiated energy on frequencies (1) Up to 490 Hz: $\frac{2400}{F_{\text{Hz}}} \mu\text{V/m}$ at 1000 ft. If above 500 watts, limit increased by $\sqrt{\frac{\text{GEN. PWR.}}{500}}$ but not above 10 $\mu\text{V/m}$ at 1 mile (2) From 490-1600 Hz: $\frac{2400}{F_{\text{Hz}}} \mu\text{V/m}$ at 100 ft. (3) Above 1600 Hz: 15 $\mu\text{V/m}$ at 100 ft. (b) Conducted energy on frequencies (1) Up to 490 Hz: 1000 $\mu\text{V/m}$ (2) Above 490 Hz: 200 $\mu\text{V/m}$	<table border="1"> <thead> <tr> <th>FREQUENCY</th><th>TOLERANCE</th></tr> </thead> <tbody> <tr> <td>13,560 kHz</td><td>6.78 kHz</td></tr> <tr> <td>27,120 kHz</td><td>160 kHz</td></tr> <tr> <td>40,680 kHz</td><td>20 kHz</td></tr> <tr> <td>915 MHz</td><td>25 MHz</td></tr> <tr> <td>2,450 MHz</td><td>50 MHz</td></tr> <tr> <td>5,800 MHz</td><td>75 MHz</td></tr> <tr> <td>22,125 MHz</td><td>125 MHz</td></tr> </tbody> </table> Radiation within the bands determined by these tolerances is not limited. Radiation outside these bands is limited as shown at the left. NOTE 3 The operator of an ISM equipment which causes harmful interference to an authorized radio service shall promptly stop operating the device. Operation shall not be resumed until the condition causing the harmful interference has been eliminated.	FREQUENCY	TOLERANCE	13,560 kHz	6.78 kHz	27,120 kHz	160 kHz	40,680 kHz	20 kHz	915 MHz	25 MHz	2,450 MHz	50 MHz	5,800 MHz	75 MHz	22,125 MHz	125 MHz
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MISCELLANEOUS EQUIPMENT Same as medical diathermy equipment. If above 500 watts, limit increased by $\sqrt{\frac{\text{GEN. PWR.}}{500}}$ but not above 10 $\mu\text{V/m}$ at 1 mile	The energy radiated and the bandwidth of emissions shall be reduced to the greatest extent practicable.																

Telecommunications
Federal Communications Commission
Code of Federal Regulations, Title 47, Parts 70-79

Type:

Class A. U.S. Government regulation

Intended Compliers:

Operators of civilian telecommunications devices

Intended Benefitters:

Operators and general public

Limits and Specifications:

Radiations emitted from antennas to meet power requirements. The maximum power output from AM broadcast transmitters is 50 kW from 535-1605 with assignable frequencies every 10 kHz starting at 540 Hz and ending at 1600 kHz. This may result in signal strengths of tens of volts per meter at 0.1 mile from the antenna.

For FM broadcast transmitters (88-108 MHz), the maximum allowed radiated power is 100 kW. At 1 mile from a dipole antenna 2,000 feet above the surrounding terrain emitting 100 kW, the field strength 30 feet above the local terrain would be about 1 volt per meter; and at 10 miles about 0.1 volt per meter. In practice the antenna at an FM station is not a simple dipole but it is directive in the vertical plane with the beam directed at or within 2° below the horizon. The fields computed above (i.e. in the main beam) are nearly 2,000 feet above ground at one mile and the field strength received on the ground will be considerably less, the actual value depending on the directivity of the antenna.

The maximum power that commercial television stations can emit is 5 MW, in the 470 to 890 MHz range. The corresponding field strength at one mile (30 feet above the ground when the transmitting antenna is a dipole 2,000 feet above the local terrain) is about 20 V/m and at 10 miles is about 2 V/m.

In practice, the TV antenna is directive in the vertical plane and the same remarks about the close-in field apply to TV stations as apply to FM stations.

International broadcast radio stations are allowed to operate on certain frequencies, the highest of which is 26.1 MHz. The allowable power is that needed to achieve the desired communication in line with good engineering judgment and practice.

The powers specified for experimental, auxiliary, and special broadcast services restrict operation to that necessary to maintain desired communication using good engineering judgment and practice. In nearly all cases, the desired communication can be achieved with relatively low power. The maximum specified power was 100 watts for a TV related auxiliary station.

General Guidance:

Each type of telecommunications service must conform to specifications given for design of equipment, monitoring and operating standards, assigned frequencies and power levels. These specifications are directed toward achieving the power at assigned frequencies required to assure reception of the radio signals at distances over which the station is assigned coverage by the FCC, and at the same time to minimize or eliminate interference with other stations.

Addendum:

There are several categories of high power (megawatt range) stations operated by the U.S. Government that should be mentioned along with FM and TV stations licensed by FCC.

There are the International Broadcast stations operated by USIA. These operate in the same frequency range as the international broadcast stations licensed by the FCC, but the USIA stations use vastly higher powers.

A second group are the low frequency Loran stations operated by the Coast Guard. These stations radiate about 2-5 MW from towers up to 1,000 feet in height in the frequency range 90-110 kHz.

A third group are the megawatt powered VLF (below 30 kHz) communication stations operated by the U.S. Navy for round the world communication.

Electromagnetic Radiation Hazards
 Technical Manual on Ground Electronics
 Engineering-Installation Agency Standard
 (GEEIA Standard)
 United States Air Force (USAF)
 T.O. 31Z-10-4, August 1966
 Replaced T.O. 31Z-10-4, October 1, 1961

Type:

Class A. USAF Standard

Intended Compilers:

Engineers and operators for Air Force ground electronics

Intended Benefitters: USAF and general public

Limits and Specifications:

0.01 watt/cm² of radio frequency power is considered to be hazardous.

All electronic devices or tubes capable of producing external x radiation in excess of 300 mR/week shall be operated under adequate radiation-shielding conditions.

General Guidance:

RF Radiation - The following general rules should be observed to prevent unnecessary exposure to microwave or RF radiation:

- a. All areas in which an RF power density of 0.01 watt/cm² is suspected or detected shall be considered hazardous and will be posted with warning signs.
- b. Limited occupancy is allowed in areas where the power density is between 0.01 and 0.1 watt/cm² (AFM 161-7). Great care must be exercised in the application of the criteria at these power levels since the consequences of accidental overexposure can be greater. A policy of prohibiting intentional exposure to power levels exceeding 0.01 watt/cm² is recommended. Areas in which the power density does not exceed 0.01 watt/cm² require no controls such as permissible time factors, control of antenna rotation, etc.
- c. Personnel shall be prohibited from working in the field of radiation of any energized antenna, waveguide, feed-horn structure, or transmission line where the measured power density exceeds 0.1 watt/cm². Theoretical calculations may be used for guidance, in lieu of actual measurements with test equipment.

- d. The practice of discharging into the surrounding area the RF output of high-power generators producing average power levels of 0.01 watt/cm^2 , or more, shall be discouraged. Dummy loads, water loads, or absorbent materials shall be used to absorb the energy output of such equipment while it is being tested.
- e. Where test procedures require free-space radiation, the radiating device (antenna) must be positioned so as to direct the radiated beam away from inhabited structures or other places where there are personnel. In the positioning of such radiating devices, care must be taken to avoid reflection of either the primary beam or accessory lobes in such a manner as to expose personnel in adjacent areas.

Ionizing Radiation - The following general rules should be observed to prevent unnecessary exposure to ionizing or x radiation:

- a. All electronic devices or tubes capable of producing external x radiation in excess of 300 mR/week shall be operated in appropriate radiationproof enclosures, unless such devices or tubes are properly shielded and such shielding has been determined to be adequate for the protection of personnel. For purposes of equipment and installations design, shielding requirements shall be based on a maximum permissible exposure of 100 mR/week. This requirement is interpreted to mean that exposures to any part of the human body of 2.5 mR/hr cannot be exceeded, assuming a 40-hour work week.
- b. The commander of any project or operation dealing with radioactive materials or equipment capable of producing x rays shall require the wearing of all dosimetric devices by personnel who may be exposed to a possible radiation hazard, and shall see that their exposures are recorded. Areas should be checked by qualified experts to determine the level of ionizing radiation and, if found necessary, to establish time limits for personnel working in the area. Supervisors of sections that are designated as x radiation hazardous areas shall keep the number of personnel in these areas to a minimum commensurate with proper maintenance and operating procedures.
- c. Personnel working in x radiation hazardous areas shall not be permitted to operate any electronic device or tube employing a peak plate voltage of 18 kV or higher with any of the shielding removed from the equipment, except where such operation is conducted in a satisfactory radiation proof enclosure.

Control of Hazards to Health from Microwave Radiation
 United States Army (USA) and United States Air Force (USAF)
 Army Technical Bulletin TB MED 270
 Air Force Manual AFM 161-7
 December 1965

Type:

Class A. USA and USAF regulation

Intended Compliers:

USA and USAF personnel in the vicinity of microwave transmitting equipment.

Intended Benefitters:

USA and USAF personnel and general public.

Limits and Specifications:

OccupancyAverage Power Density

Unlimited

less than 10 mW/cm²

Limited

10 to 100 mW/cm²

$$\text{Exposure time (minutes)} = 6000/X^2$$

X in mW/cm²

Denied

greater than 100 mW/cm²

General Guidance:

When feasible, microwave beams should be located to minimize exposures in areas adjacent to and within military installations.

Note: This regulation supersedes Air Force Pamphlet Number 160-6-13 issued by USAF Medical Service in May 1958.

Radiation Limits, Microwave and X Radiation Generated by
Ground Electronic Equipment (As Related to Personnel Safety)
United States Air Force
MIL-R-9673 B (USAF), 15 September 1961

Type:

Class A United States Air Force regulation

Intended Compliers:

USAF personnel and contractors

Intended Benefitters:

USAF and general public

Limits and Specifications:

The supplier of the electronic equipment must define areas of specified RF power density 10 mW/cm^2 or greater.

Radiation limits are set only for x ray radiating at 2.5 mR/hr at 12 inches from an accessible surface.

General Guidance:

The contractor shall produce information before and after equipment has been delivered describing the areas of radio-frequency power densities greater than $.01 \text{ W/cm}^2$. Requirements are included for x ray shielding of the equipment to 2.5 mR/hr within 12 inches of an accessible surface. The survey equipment used for radio-frequency and x rays shall be approved by the Air Force. Hazard signs shall be posted where x radiation emanation is higher than that stated.

Technical Manual for Radio-Frequency Radiation Hazards
Department of the Navy, Naval Ships Systems Command
NAVSHIPS 0900-005-8000, July 1966

Type:

Class A. U. S. Navy manual

Intended Compliers:

U. S. Navy personnel

Intended Benefitters:

U. S. Navy personnel and public

Limits and Specifications:

Continuous exposure: 10 mW/cm^2

Intermittent exposure: 300 mJ/cm^2 for a 3 second interval

General Guidance:

Biological effects of radio frequency radiation are described. Equations are given for calculating the on-axis power density radiated from large aperture antennas. Methods for measuring the power density are given.

Safety Precautions for Shore Activities
United States Navy (USN)
NAVSOP-2455 April 1965

Type:

Class A. U.S.N. Mandatory, Advisory and Supplemental Precautions

Intended Compliers:

U.S.N. personnel

Intended Benefitters:

U.S.N. and general public

Limits and Specifications:

Continuous exposure:

10 mW/cm²

Intermittent exposure:

300 mJ/cm² per 3 second period of time.
This is equivalent to 10 mW/cm² for a 30 second period of time.

General Guidance:

Chapter 4 - paragraph 0415-8, cautions against dangers associated with fueling aircraft near radar beams.

Chapter 15 - paragraph 1543 - Radio Frequency Radiation Hazards - Radiated beams from antennas of electronic equipment can produce hazardous conditions such as shock, ignition of combustible materials, trigger electro-explosive devices, heat objects in beam, biological damage. Paragraph 1544 deals with x-radiation hazards from high voltage electronic equipment. Paragraph 1545 deals with work on antennas. Paragraph 1546 deals with cathode ray tubes. Paragraphs 1547 and 1548 deal with radioactive materials used with Radiac equipment.

**Radio-Noise and Field-Strength Meters,
0.015 to 30 Megacycles/Second, Specifications for
United States of America Standards Institute (USASI)
USASI - C 63.2-1963**

Type:

Class B. USASI Specification for Meter

Intended Compliers:

Manufacturers and users of radio equipment

Intended Benefitters:

Compliers

Limits and Specifications:

Not applicable

General Guidance:

This specification recommends the proper operating characteristics of instruments for measuring voltages and power at radio frequencies. The instruments are described. Criteria are established for sensitivity, accuracy, output meter scale, antennae, input impedance, selectivity and bandwidth, and rejection of spurious signals.

Radio-Noise and Field-Strength Meters
20 to 1,000 Megacycles/Second, Specifications for
United States of America Standards Institute (USASI)
USASI-C 63.3 - 1964

Type:

Class B. USASI Specification for Meter

Intended Compliers:

Manufacturers and users of radio equipment

Intended Benefitters:

Compliers

Limits and Specifications:

Not applicable

General Guidance:

This specification recommends the proper operational characteristics of radio-frequency voltage or power-measuring instruments.

The basic measuring set is briefly described. Criteria are established for sensitivity, accuracy, output meter scale, antennae, input impedance, selectivity and bandwidth, and spurious signal rejection. The time constants of the detector circuit are given for average, quasi-peak, and peak-reading circuits.

Radio-Noise Voltage and Radio-Noise Field Strength,
0.015 to 25 Megacycles/Second, Low Voltage Electric Equipment,
and Nonelectric Equipment, Methods of Measurement of
United States of America Standards Institute (USASI)
USASI-C 63.4 - 1963

Type:

Class B. Standard for Measurement

Intended Compliers:

Manufacturers and Users of low voltage electric and
nonelectric equipment

Intended Benefitters:

Compliers

Limits and Specifications:

Not applicable

General Guidance:

The standard defines conditions under which measurements may be made in the laboratory and in outdoor tests, and specifies the environmental noise level to be at least 6 db. below the allowable limit of the applicable standard. Units of measurement for radio noise are in microvolts and for field strength are in microvolts per meter.

Safety Level of Electromagnetic Radiation with Respect to Personnel
United States of America Standards Institute (USASI)
USASI C 95.1 - 1966

Type:

Class B. USASI Standard

Intended Compliers:

Users of equipment emitting electromagnetic radiation

Intended Benefitters:

Users of equipment and public

Limits and Specifications:

Power density: 10 mW/cm^2 for periods of 0.1 hour or more

Energy density: 1 mW hr/cm^2 during any 0.1 hour period

Radiation characterized by a power level tenfold smaller will not result in any noticeable effect on mankind. Radiation levels which are tenfold larger than recommended are certainly dangerous.

General Guidance:

The guide recommends exposure limit numbers for continuous or intermittent radiation under normal environmental conditions. The guide explains that the recommended exposure limits do not apply in all cases, such as in extreme environments, or when the persons exposed may have circulatory or other health problems. The formulated recommendations pertain to both whole body irradiation and partial body irradiation. The recommended exposure levels or less may be achieved by source modification, medium modification or personal protection devices.

Radio-Frequency Radiation Hazard Warning Symbol
United States of America Standards Institute (USASI)
USASI C 95.2 - 1966

Type:

Class B. USASI Standard

Intended Compliers:

Users of equipment emitting biologically hazardous
electromagnetic radiation

Intended Benefitters:

Users of equipment and public

Limits and Specifications:

Not applicable

General Guidance:

The warning symbol shall consist of a red isosceles triangle above an inverted black isosceles triangle, separated and outlined by an aluminum color border. The words "Warning Radio-Frequency Radiation Hazard" shall appear in the upper triangle. Other warning information, at the discretion of the user, shall appear in the lower triangle.

Aircraft Fueling on the Ground
National Fire Protection Association (NFPA)
NFPA No. 407-1965
USASI No. Z119.1-1966

Type:

Class B. NFPA standard and USASI standard

Intended Compliers:

Aircraft fuelers

Intended Benefitters:

Aircraft fuelers and public

Limits and Specifications:

None

General Guidance:

Among the precautions required for the various hazards associated with fueling aircraft on the ground are precautions applying to aircraft and personnel in the vicinity of radar beams.

Recommended Practice for Measurement of Field
Intensity Above 300 Mc from Radio-Frequency
Industrial, Scientific, and Medical Equipment
American Institute of Electrical Engineers (AIEE)
IEEE 139 (formerly AIEE 950)
April 1952

Type:

Class B. IEEE Standard

Intended Compliers:

Users of industrial, scientific and medical electronic equipment

Intended Benefitters:

Users and general public

Limits and Specifications:

Not applicable.

General Guidance:

This is a recommended practice for accurate measurements of radio-frequency generating equipment over 300 MHz.

The recommended practice gives a brief introduction to two fundamental methods of measuring field intensity using dipole, reflector, and horn antennae built to specifications in the report. General precautions and techniques are given regarding impedance matching, accuracy, and equipment associated with measurement.

Note:

The American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE) merged into the Institute of Electrical and Electronics Engineers (IEEE) on January 1, 1963. As a result, all the AIEE standards were renumbered into a new IEEE series. AIEE No. 950, April 1952, was renumbered as IEEE 139, April 1952, with no change in title or in text.

Microwave Radiation Hazards
California State Department of Public Health
Bureau of Occupational Health

Type:

Class C. California State Guide

Intended Compliers:

Users and manufacturers of microwave equipment

Intended Benefitters:

Users of Microwave equipment and public

Limits and Specifications:

The working tolerance levels for whole body exposure have been established in terms of field intensity flux, in watts or milliwatts per square centimeter (W/cm^2 or mW/cm^2).

The Bell Telephone Laboratories have set up the following tolerance levels:

- a. more than $.01 \text{ watt}/\text{cm}^2$ - potentially hazardous
- b. 0.001 to $.01 \text{ watt}/\text{cm}^2$ - safe for incidental or occasional exposure
- c. less than $.001 \text{ watt}/\text{cm}^2$ - safe for indefinitely prolonged exposure of permanent assignment

General Guidance or Specifications:

A program of safety must include evaluation of the hazard in occupied or potentially occupied areas. For this evaluation information is needed about (1) frequency of wave, power level, gain, duty cycle, angle of rotation, and of microwave installation, (2) calculated distances from the antenna to the boundary of potentially hazardous zones, (3) locations of working personnel and the general population with respect to the radiating antennas, (4) presence of highly reflective surfaces that may intensify beams in specific locations, and (5) accurate measurement of existing radiation intensity levels by reliable instruments in the hands of personnel well trained in the use of such equipment.

The guide includes suggestions for measuring microwaves.

The information obtained from surveys is evaluated in terms of biological effects of microwaves which are summarized in the following table.

Biological Effects of Microwaves

Frequency Mega Hertz MHz	Wavelength (cm)	Site of Major Tissue Effects	Major Bio- logical effects
More than 10,000	less than 3	Skin	Skin surface acts as reflector or absorber with heating effects
10,000	3	Skin	Skin heating with sensation of warmth
10,000-3,300	3-10	Top layers of skin, lens of eye	Lens of eye particularly susceptible
10,000-1,000	3-30	Lens of eye	Critical wavelength band for eye cataracts
1,200-150	25-200	Internal body organs	Damage to internal organs from overheating
less than 150	Above 200		Body is transparent to waves above 200 cm

Protection from microwave radiation can often be accomplished by shielding in the form of area barriers or protective clothing. Radiation can be absorbed by certain materials such as animal hair impregnated with a rubber and graphite mixture or reflected by wire mesh constructed according to exact mathematical calculation. The major requirements of an effective protection garment area:

reduction of high-level fields external to the garment to safe levels inside the garment,

protection against high-voltage gradients built up in the garment, and

minimum restriction of visibility, mobility and dexterity.

Since absorption suits would be too cumbersome to wear, the most reasonable technique is to reflect the energy. A suit was designed and used that withstands severe mechanical and environmental tests; it allows complete freedom of movement without obstructing the wearer's visibility. It can be worn with safety in an electromagnetic field whose power density is 10,000 times more intensive than the present safe limit.

Since the eyes are particularly susceptible to damage, suitable eye protection should be used whenever a potential exposure exists. Devices, consisting of metallic covers perforated with minute holes, are available.

In the manufacture and testing of Klystron tubes and other sources of microwaves, smaller beams may be released. It is essential, therefore, that potentially hazardous power densities even of small areas be recognized and rendered harmless.

In addition to the direct hazards from the microwaves themselves, one must consider the possibility of exposures to the by-product emissions, such as X rays, ultraviolet rays, and infrared rays from the Klystron tubes. Furthermore, the high voltages used for generation of microwaves present the possibility of injury by electric shock.

The Navy Department has rules relating to aircraft fueling in the presence of radar beams, and the National Fire Protection Association (NFPA) has set up a Standard for "Aircraft Fueling on the Ground" (Number 407) which has guidance procedures for fueling operations where radar beams are in use.

For rules of Navy Department see: Safety Precautions for Shore Activities, U.S. Navy Department, NAVSO P-2455, April 1965, Chapter 4, paragraph 0415-8, Chapter 15, paragraph 1543.

Temporary Safety Regulations for Personnel in the Presence of
Microwave Generators
U.S.S.R. Ministry of Hygiene
Publication Number 273-58, November 26, 1958

Type:

Class A. U.S.S.R. Ministry of Hygiene Regulation

Intended Compliers:

Users of microwave generators

Intended Benefitters:

Users of microwave generators and public

Limits and Specifications:

1. Irradiation during entire working day: 0.01 mW/cm^2
2. Irradiation less than 2 hours per working day: 0.1 mW/cm^2
3. Irradiation less than 15 or 20 minutes per working day: 1.0 mW/cm^2 . In this case protective goggles are required.

General Guidance:

Operating precautions and working area restrictions are presented for microwave equipment and laboratories. Instructions are given for periodic surveys, personal protection and medical examination.

Radiation Hazards from Electronic Equipment
Canadian Standards Association
CSA Standard Z65-1966

Type:

Class B. CSA Standard

Intended Compliers:

Manufacturers and users of electronic equipment

Intended Benefitters:

Users of electronic equipment and public

Limits and Specifications:

(Permissible Levels of Radiation)
Radiofrequency Fields for People

For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 to 100,000 megacycles per second, the radiation level of 10 milliwatts per square centimetre as averaged over any possible 0.1 hour period shall not be exceeded. This means:

- (a) A power flux of 10 milliwatts per square centimetre for periods of 0.1 hour or more; and
- (b) An energy flux (total) of 1 milliwatt-hour per square centimetre for periods up to 0.1 hour.

This requirement applies whether the radiation is continuous or intermittent.

Ionizing Radiation for People

The exposure and cumulative exposure of persons to ionizing radiation shall be kept as low as possible.

An area where the dose for occupants could be in excess of 1.5 rems in a year shall be established as a controlled area.

Maximum permissible doses for individuals are given in detail in Publication 6 (1962) of the International Commission on Radiological Protection and in the Atomic Energy Control Regulations. However, for purposes of planning, the following maximum permissible doses to whole body, blood forming organs, gonads, and eyes shall be observed:

- (a) For occupationally exposed persons:
 - (i) In any period of 13 consecutive weeks - 3 rem;
 - (ii) In any period of 52 consecutive weeks - 5 rem; and
- (b) For all other persons, in 1 year - 0.5 rem.

Radiofrequency Radiation for Electric Blasting Caps

Tables and conditions are given for safe distances for various levels of radiated power.

General Guidance:

Human Body Hazards from RF Fields

This part covers a method for preventing possible harmful effects on mankind, resulting from exposure to electromagnetic radiation in the frequency range from 10 to 100,000 megacycles per second. It applies to all radiations originating from radiostations, radar equipment and other possible sources of electromagnetic radiation such as used for communication, radio-navigation, and industrial and scientific purposes. It is not intended to apply to the deliberate exposure of patients by or under the direction of practitioners of the healing arts.

Hazards to Humans from Ionizing Radiation

This part applies to hazards from ionizing radiation produced incidentally by electronic components such as high voltage rectifiers, cathode ray tubes, television tubes, klystrons, magnetrons, thyratrons, and electronic tubes containing deliberately added radioactive material. It does not apply to hazards from ionizing radiation originating from X-ray or other electronic equipment intended for the production of ionizing radiation or from radioactive material except as noted.

Electric Blasting Cap Hazards from Radio Frequency Radiation

This part provides a standard of safe usage and transportation of electric blasting caps, delay type electric blasting caps, and electric squibs in the presence of radiofrequency (RF) radiation. The safe distances and currents apply only to caps which have been declared authorized under the provision of The Explosives Act of Canada. This part applies to radio transmitters such as broadcasting, beyond-the-horizon, mobile communications and other similar transmitters, as well as to television and radar transmitters. It also includes industrial RF heaters, and equipment for geophysical surveys particularly where aircraft are involved. This part does not apply to fireworks or flammable liquids, or to explosives other than electric blasting caps and squibs. It does not consider RF fields from lightning or electromagnetic fields from power lines.

Safety Precautions Relating to Intense Radio-Frequency Radiation
The British Post Office (BPO)
25822 Wt. 2006-37290 K24 4/60
C.P. LTD. 999/226
London

Type:

Class C. BPO recommendation

Intended Compliers:

Users and manufacturers of RF equipment

Intended Benefitters:

Users of equipment and public

Limits and Specifications:

For frequencies between 30 and 30,000 MHz the recommendations are:

- (a) for continuous daily exposure 10 mW/cm^2
- (b) in the case of pulse systems the radiation is to be averaged over complete trains of pulses, including any intervals between pulse trains.

General Guidance:

The report gives the maximum permissible exposure limits of 10 mW/cm^2 and the interpretation of these values for pulsed or rotating equipment. Details are given for protection of the general public from fixed, mobile, and industrial and scientific equipment. Protection consists of placarding, fencing areas, and preventing dangerous levels radiated energy from reaching the public. Protection of operating and maintenance personnel entails shielding, protective clothing and fences. Details are given.

Exposure Precautions:

	General Public	Operating and Maintenance Personnel	Research, Experiment and Testing Personnel
Protection	placards fenced areas directing beam	shields protective clothing placards	shields protective clothing placards
Measurement	Average over 1 second except for rotating antennas	Average over 10 seconds for close-field rotating devices	Average over 10 seconds for close-field rotating devices
Special	Applies to mobile, fixed stations, and scientific, medical and industrial equipment	Certain less vulnerable parts of the body may momentarily enter high field areas, e.g., hands and feet.	should have health safety officer make periodic safety checks

RF measuring devices are specified to have errors of $-0, + 2$ db in the plane-wave power levels of 5 to 20 mW/cm². Other operating specifications for the measuring equipment are included.

Directions are given for action to be taken when exposures above the limits have occurred.